Weight and Nitrogen and Calcium Content of the Annual Litter Fall of Forests in the South Carolina Piedmont[1]

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ABSTRACT

The annual fall of litter was measured in stands of pine, mixed pine-hardwood, and hardwood in the South Carolina Piedmont. The total amount of litter (including twigs, bark, and fruit) dropped annually ranged from 4,059 to 5,619 pounds per acre on an oven-dry basis. Considering leaf fall alone, the annual drop ranged from 2,938 pounds in a 30- to 40-year old stand of shortleaf pine to 4,476 in a 25-year old loblolly pine stand.

The content of nitrogen, calcium, and magnesium in freshly fallen leaves was determined for 14 tree species. The foliage of both loblolly and shortleaf pines was found to contain less of these elements than any of the hardwood species. Based on these chemical determinations and the annual leaf fall, estimates are given of the total amount of these nutrients returned to the forest floor by the annual leaf fall in the nine stands studied. The hardwood stands were found to return about twice as much nitrogen, three times as much magnesium, and five times as much calcium in their leaf fall as did the pine stands. Information given as to the nutrient content of the common forest species and in the litter fall of representative stands can be used by the forester to evaluate the effect of his management practices upon soil conditions.

IN the Southeast, soil organic matter decomposes rapidly and the general nutrient level of the soils is low. For this reason farmers find it necessary to make heavy applications of fertilizers and to grow cover crops to insure good yields. Since the same processes which deplete organic matter and nutrients operate in forest land as in farm land, it is fortunate for the forester that his tree crop returns large amounts of organic matter and essential elements to the soil surface by the annual fall of leaves, twigs, bark, and other organic debris. However, there are great differences in chemical composition of the organic matter contributed by the various species. When these differences are known, it is possible for the forester to control the species present in the stand to most effectively maintain or improve soil conditions. The present study was made to determine the annual litter fall and its content of nitrogen, calcium, and magnesium for some representative forest types in the South Carolina Piedmont. The objective was to determine which tree species or mixtures of species will be most useful in improving soil conditions in this region where the present forest land is actually worn-out and abandoned farm land.

Methods

This study was made on the Calhoun Experimental Forest in Union County, S. C. It is based on nine sample plots located in representative upland forest types of the South Carolina Piedmont. Three of the plots are in pine forest types, three in mixed pine-hardwood, and three in hardwood types. Table 1 gives the characteristics of the forest stand on each plot.

One of the pine stands is mixed loblolly and shortleaf, another is pure shortleaf, and the third is a 10-year old loblolly pine plantation. The latter was selected because loblolly pine is the species used almost exclusively for forest plantings in the Piedmont. In the loblolly pine plantation, trees from 4 to 6 inches d.b.h. make up 95% of the basal area. In the other two pine stands about 75% of the basal area is from trees 5 to 10 inches d.b.h. One of the mixed stands is about half pine and half hardwood (with respect to basal area), and the other two are about three-quarters hardwood. About 18 species of hardwoods are found growing in each of the mixed pine-hardwood areas. Two of the hardwood stands were converted from pine-hardwood by the cutting of the pines about 10 years ago. Each has about 1,170 stems per acre, ranging up to 15 inches in diameter, although 80% are below 5 inches in diameter. The third hardwood stand, on land that has never been cleared, is a relic of the former old-growth hardwoods, and is now predominantly hickory because of the selective removal of other species during the past 150 years. It does not truly represent the oak-hickory climax forest present before settlement, but it is the only known remnant in the county that escaped clear cutting. The three hardwood stands each contain about 13 different species.

The soils on all plots are derived from igneous parent material, and the soil series represented are Helena, Vance, Cataula, and Lloyd.

To obtain an estimate of litter fall, three wire screens were randomly placed in each plot about 6 inches above the forest floor. Each screen covered an area of 9 square feet and had wooden sides about 6 inches high. The traps were set out on September 12, 1950, and the material falling into them was collected every 8 weeks through September 12, 1951. Most of the leaf material dropped before February 1, 1951, while the fall of twigs, bark, and fruit was more constant throughout the year. When the material was taken from the traps, the twigs, bark, and fruit were separated from the leaves, and the leaves were divided into the various species. The leaves were divided into species so that the contribution of each to the total amount would be known. The material was then oven-dried at 90° C and weighed. The total fall of pine

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Table 1.—Descriptions of the nine Piedmont forest stands studied.

Stand	Pine component	Principal hardwood species present	Age of stand in years	Basal area, in square feet per acre		
				Pine	Hardwood	Total
			Pine Stands			
1	Loblolly 75% Shortleaf 25%		20–25	102.0	0.6	102.6
2	Shortleaf		30–40	124.0	1.9	125.9
3	Loblolly (Planted 1941)		10	103.3		103.3
			Pine-Hardwood Stands			
4	Shortleaf	Dogwood E. Red Oak Red Maple	1–60	42.7	34.1	76.8
5	Shortleaf 90% Loblolly 10%	White Oak E. Red Oak Black Oak Yellow-poplar Hickories	1–40	22.8	66.4	89.2
6	Shortleaf	White Oak Black Oak Dogwood	1–60	25.3	54.5	79.8
			Hardwood Stands			
7		Yellow-poplar Hickories Dogwood	1–45	0.5	80.6	81.1
8		Hickories Yellow-poplar Dogwood Red Maple E. Red Oak	1–150	2.6	96.9	99.5
9		Hickories White Oak E. Red Oak Red Maple	1–50	4.4	57.6	62.0

needles, hardwood leaves, and twigs, bark, and fruit are listed in table 2 for each study area.

The material collected in the frames was not used for foliar analyses because it was subjected to weathering. To obtain material for the chemical determinations, collections were made of mature, undecomposed, freshly fallen leaves in the fall of 1950 before they had been subjected to the leaching effect of rain. The samples were oven-dried, passed through a 20-mesh sieve in a Wiley mill, and stored in air tight containers for later analyses.

Nitrogen was determined by the Gunning Method modified to include nitrates as outlined in A.O.A.C. (2). Calcium was precipitated as calcium oxalate and magnesium precipitated as magnesium ammonium phosphate according to methods used by the Bureau of Plant Industry at the U.S. Field Laboratory for Tung Investigations at Gainesville, Fla. (6). Table 3 lists the species studied and the nitrogen, calcium, and magnesium content expressed as percent of the oven-dry weights of the material analyzed.

As shown in table 2, total litter fall varied from 4,059 pounds per acre in the loblolly pine plantation to 5,619 pounds in the 25-year old pine stand. Twigs composed about 15% of the litter dropped in the hardwood stands and about 24% of the litter dropped by the older pine. The 10-year old loblolly plantation still retained most of its branches, and consequently dropped less twigs than the older pine stands.

Considering the leaf fall alone, the annual drop

Table 2.—Annual litter fall in nine Piedmont forest stands, Union County, S. C.

Stand	Stand composition	Pounds per acre			
		Leaves		Twigs, bark, fruit	Total
		Pine	Hardwoods	All species	All species
1	Pine	4,476 ± 108*	———	1,143 ± 145	5,619 ± 246
2	Pine	2,938 ± 53	———	1,165 ± 173	4,103 ± 226
3	Pine	3,771 ± 127	———	288 ± 122	4,059 ± 245
4	Pine-hardwood	1,741 ± 172	1,677 ± 142	1,389 ± 155	4,807 ± 416
5	Pine-hardwood	556 ± 100	2,618 ± 256	962 ± 53	4,136 ± 347
6	Pine-hardwood	1,368 ± 66	2,457 ± 59	1,517 ± 250	5,342 ± 321
7	Hardwood	———	3,697 ± 124	812 ± 165	4,509 ± 139
8	Hardwood	———	4,103 ± 159	662 ± 74	4,765 ± 209
9	Hardwood	———	3,654 ± 243	577 ± 130	4,231 ± 204

*Standard error of mean.

Table 3.—Nitrogen, calcium, and magnesium content of various Piedmont tree species growing in Union County, S. C.

Species	Number of determinations	Percent of element on oven-dry basis		
		Nitrogen	Calcium	Magnesium
Eastern redbud, *Cercis canadensis*	4	1.16 ± 0.009*	2.96 ± 0.012	0.22 ± 0.007
Eastern red oak, *Q. borealis* v. *maxima*	14	1.00 ± 0.028	1.42 ± 0.065	0.36 ± 0.023
White oak, *Q. alba*	12	0.92 ± 0.030	1.69 ± 0.049	0.30 ± 0.009
Blackjack oak, *Q. marilandica*	12	0.85 ± 0.070	0.96 ± 0.047	0.28 ± 0.020
Post oak, *Q. stellata*	10	0.80 ± 0.017	0.97 ± 0.037	0.22 ± 0.007
Black oak, *Q. velutina*	10	0.70 ± 0.040	1.04 ± 0.084	0.23 ± 0.022
Southern red oak, *Q. falcata*	10	0.60 ± 0.008	1.06 ± 0.050	0.23 ± 0.011
Flowering dogwood, *Cornus florida*	16	0.68 ± 0.014	3.38 ± 0.090	0.53 ± 0.021
Hickory, *Carya carolinae-septentrionalis*	12	0.62 ± 0.017	2.78 ± 0.152	0.62 ± 0.014
C. tomentosa				
C. ovalis				
Yellow-poplar, *Liriodendron tulipifera*	14	0.53 ± 0.012	2.61 ± 0.130	0.72 ± 0.052
Red maple, *Acer rubrum*	8	0.51 ± 0.050	1.32 ± 0.122	0.33 ± 0.050
American sweetgum, *Liquidambar styraciflua*	8	0.49 ± 0.006	1.30 ± 0.045	0.47 ± 0.032
Shortleaf pine, *Pinus echinata*	14	0.45 ± 0.040	0.59 ± 0.011	0.19 ± 0.014
Loblolly pine, *Pinus taeda*	16	0.31 ± 0.007	0.43 ± 0.025	0.15 ± 0.007

*Standard error of the mean.

ranged from 2,938 pounds per acre for the 30- to 40-year old shortleaf pine stand to 4,476 pounds for the 25-year old pine stand.

The leaf fall for these pine stands was about the same as given for second growth slash and longleaf pines by Heyward and Barnette (7), who found that the annual leaf fall in Florida averaged from 2,400 to 3,500 pounds per acre. The leaf fall of the mixed stands was somewhat greater than the values of 2,600 to 3,100 pounds per acre reported by Sims (12) for oak-pine stands in the North Carolina mountains. The leaf fall for the hardwood areas was greater than that reported by Chandler (4), who found that in New York the annual fall varied from 2,435 to 3,020 pounds per acre. With the exception of the old-growth hickory forest, the values for the hardwood stands were less than the 4,050 pounds reported by Hursh (8) for the Southern Appalachian mountains. It must be kept in mind when comparing these values with those of other workers that the present study represents only one year's fall. It is well known that variations occur from year to year. Alway and Zon (1) found in the Lake States that the annual leaf fall varied as much as 25% between years.

The results of the chemical analyses for the species studied are found in table 3. The highest nitrogen content, 1.16%, was found in the leaves of redbud, and the lowest, 0.31%, in loblolly pine. The value for red maple was practically identical with that found by Coile (5) in the lower Piedmont region of North Carolina. The percent of nitrogen reported by him is 0.3 higher than was found in the present study for white oak, black oak, yellow-poplar, and dogwood; and 0.5 higher for both pines.

Chandler (4) gives values for yellow-poplar and red maple in New York which compare closely with those reported here, but his values for red and white oaks are somewhat lower.

The calcium content of all hardwood species was much higher than that of the pines. Fallen leaves of dogwood, redbud, yellow-poplar, and the hickories had more than 2% calcium on the basis of dry weight. For other hardwood species the calcium content was between 0.96% and 1.69%, while for the pines the values were less than 0.60%. In this study, species were ranked on the basis of calcium approximately as in Coile's work (5). The percent calcium deviated for some species, but it was almost identical for black oak and dogwood.

For the species studied, magnesium content of the fallen leaves varied from 0.15% to 0.72% of the dry weight. Values for red oak, white oak, and the hickories were comparable with those given by Lutz and Chandler (10), but yellow-poplar was 0.30% less than their value.

No correlation was found between the chemical composition of the leaf material and the soil series on which the trees are growing. This is in agreement with the results of Bard (3), who found that the calcium content of foliage varied little for most species with varying lime content in the soil, and also that there was no correlation between the nitrogen content of the soil and that of leaf samples.

From the weight of leaves dropped by each species in the different stands and the percent of nitrogen, calcium, and magnesium for the species, it was possible to estimate the quantity of elements returned to the forest floor by the annual leaf fall. Table 4 gives these estimates for each stand studied. The values in this table are based only on the annual leaf fall. No chemical analyses were made of twigs, bark, and fruit.

There was little difference in nitrogen return in the hardwood and the mixed pine-hardwood stands, but both of these types returned a greater amount of this element than did the pine stands. The amounts of cal-

Table 4.—Quantity of element returned to forest floor annually in leaf fall.

Stand	Stand composition	Pounds per acre		
		Nitrogen	Calcium	Magnesium
1	Pine	15.07	20.61	7.05
2	Pine	13.22	17.32	5.58
3	Pine	11.69	16.21	5.65
4	Pine-hardwood	19.58	37.35	8.63
5	Pine-hardwood	24.51	42.79	9.06
6	Pine-hardwood	26.58	51.52	11.22
7	Hardwood	23.04	88.44	20.85
8	Hardwood	27.50	102.36	22.58
9	Hardwood	29.10	75.45	15.90

cium and magnesium returned were least for pine, intermediate for pine-hardwood, and greatest for hardwood stands.

The difference in nitrogen and calcium return between the three broad forest types is large enough to be of considerable practical importance in forest management. Soils of this region are generally low in both elements, and both are needed to insure healthy growth. For shortleaf pine, Roth *et al.* (11) found that trees with little leaf disease showed a marked deficiency in both elements. Lunt (9) has pointed out the significance of nitrogen and calcium in determining the rate and decomposition of organic matter which influences both soil fertility and physical properties. The information given in table 3 provides guidance for the forester in managing stand composition for soil improvement. For example, where predominance of pine is sought for economic reasons, it should be possible to encourage an understory of redbud and dogwood for soil improvement without causing serious difficulty in maintaining pine. Where soils have been seriously depleted by past agricultural use and pines are growing poorly, hardwoods should be favored because of their benefit to the site.

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